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ABSTRACT

The presentation of physics content knowledge in conjunction with the lack of examples in solving problems leads high school students to struggle with mathematical problem solving in physics courses. This paper explains the importance and necessity of having mathematical courses for all high school students. (YDS)

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A MATHEMATICAL PHYSICS FOR ALL STUDENTS PART II

In a previous article with the same name in the "In My Opinion" column in the December 1999 TPT I contended that the mathematical problem solving course In high school physics is viable for most students, average or better, if a lot of help is given to the students over a long period of time, drills and practices are used in problem solving, and calculators are used (even provided by the school). (1).

For a long time the most popular physics text used in U.S. high schools was Modern Physics. (2). Often, the use of this text was devistating to the high school physics students because of the lack of examples in solving the problems in the text as well as the lack of drills and practices of these problems. The difficulties in doing the mathematical problem solving affected both the above average student, who most often took physics(3), and average and at-risk students as well. This is one reason that physics programs, especially in the cities, have either been lost or substantially reduced in size (4). Another reason is that the teaching of physics did not include direct instruction where the student was given problem solving with few examples under the guise of having the students "think" enough and supposedly then would be able to solve the physics problems. The truth is that even the teachers of physics did not learn their physics that way, often getting various forms of help such as tutoring from friends and relatives. In fact,a vast industry has grown up publishing "problem solvers" that give examples of all kinds of common physics problemsranging from introductory physics to advanced courses. Very few students have the time to think about the solutions to physics problems unnecessarily made difficult. I helped an honors physics student enormously by simply telling his mother to buy a Shaum's College Physics (5).Knowledge of these books of solutions to problems is sometimes purposefully withheld from the high school students especially in order to make the students think the course is esoteric and difficult as was the case with this young man. Also, now publishers are providing high school physics texts with drills and practices and many more examples of how to do the physics problems in the text. The result was a shift from using Modern Physics as the preferred high school text to texts such as the Murphy and Smoot Physics: Principles and Problems. The reason for the shift was the use of drills and practices in the text as well as having an example for each type of problem. When the Modern Physics was the preferred text and only one that was purchased most often, teachers such as myself had to take one or two problems from each section and not only provide and example of how

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to solve them, but also provide drills and practices to effect learning.My experience has shown that the vast majority of high school students can pass a mathematically oriented problem solving physics course if the problems are made relatively simple, examples are given for each type of problem, and drills and practices are employed in the problem solving. Problems of a more complicated nature can also be solved by most high school students if an example is given as well and drills and practices are used. An aggressive teacher role in giving the students problem solving help is necessary, however. (6). We are not reaching all the students who are capable of passing this type of course, and in fact often the students are turned off if the course is made difficult. Often, physics teachers and writers of physics texts forget that it is the solving of a problem that leads to the the confirmation of one's skill, not the struggling with it. As B.F. Skinner stated pleasurable consequences lead to positive reinforcement and learning. With success students become more apt to stay in the field thereby increasing college enrollments (7).This is another case in education where more turns out to be less.

Also, to reach all of these students a above average effort must be made in grading. Many students will not put in the time or effort to do the work assigned unless it is graded. Since we move along every day in the text, this may mean grading as many as 150 papers a day, one from each student. In two months, I grade approximately 4000 to 5000 papers. Daily grading of some kind is needed since we in physics know that if the student does not do Monday's assignment, he cannot very well to Tuesday's or Wednesday's work since each day's work builds upon the work from the day before. Often, I have to spend one or more days a weekend grading papers.

Since very often a physics lab must be done within a span of 40-50 minutes, I try to show as many students how to do the lab so that the lab can be completed in one period. Rarely, do I print up a lab and hand it out. I put the lab on the board and often the students can copy it within 10 minutes especially if some kind of motivation is given. The purpose of this approach is to have the student interact with the experiment in some way and to have the student become familiar with the vocabulary of the instrumentation for example The students almost always have to take data, and at least find an average of some kind. Almost all the students can do basic mathematical modeling, finding an equation to approximate a curve after a few months if substantial help is given by the instructor. Very often, I am on my feet all period assisting students with data taking, lab setup, and calculations as well as problem solving all period.

The reason we must give the mathematical course is that this type of course enhances logical thinking and reasoning which transfers to all aspects of life Literacy in science is not memorizing definitions of words and concepts, rather it Is the capability of doing the physics using the language of physics, mathematics. We must start out small, giving relatively basic problems to be solved, continually

provided a lot of help is given by the teacher and the problems are kept simple. Sometimes, a calculator may be needed just to help the students temporarily overcome their math deficits besides speeding up the problem solving process. Many of these students would not have the opportunity to experience what real science is like without the mathematics in the course, nor be capable of doing a physics or chemistry course in higher education of any quality.

Furthermore, the fundamental laws of physics are often stated as equations. Equations are means of expressing relationships among variables and are solved by mathematical means. In high school and in elementary college physics the mathematics used is mainly algebra with possibly a little trigonometry. The reason the student needs his basic algebra is that the language of physics is mathematics and to be successful in the standard mathematical course, the student of physics must have good command of the mathematics needed to solve for unknowns in the equations of the course. As we all know, many students are not solid in their algebra, and must often must be helped. Just knowing one's algebra and/or calculus is usually not enough to solve physics equations which are usually in the form of applications problems. A student must also have specific information about the problem itself such as knowing certain constants, methods of isolating important factors in the problem itself, and ways of putting together a proper equation so that the required variable can be solved for.

The object of a mathematical course for all high school students, the standard basic physics course most often given to the upper 25% of the high school student body, is not just physics literacy. Rather, it is also, and possibly more importantly, the equality of opportunity since many careers, often well paying technical careers such as in computer technology, technicians of all kinds, chemist, engineer and physics and chemistry teacher, are unattainable unless the student has the mathematical high school course first. The doors in the sciences, medicine, and technology are often closed to those students who cannot solve a physics and/or chemistry problem. As I have pointed out before in an earlier article of this type, many average and even at-risk students can succeed in the basic mathematical high school physics course if proper methods are used. They do not have to be relegated to the lower paying jobs and/or careers as is often the case because they cannot do a basic physics and/or chemistry problem. The need for the standard and basic mathematical course for all students is essential so that all high school students have the same opportunities to be what they can be. Certainly, an above average teaching effort must be made, but we must remember that the lives of many more students can be enhanced if we give them the mathematical course and not short change them with a qualitative course which really does not move them forward or prepare them for life in a technological world.

Finally, the standard mathematical course provides the student with an opportunity to generate organized thinking and rationality Many students are mentally careless. By having to organize a solution to a physics problem, stating the proper formula, isolating the proper factors and assigning them values, and substituting the values into the formula and then performing the proper mathematical operations, the students gain a sense of mental orderlyness and rationality. Especially, if students are given a lab a week or more in which they take data , set up a data table and find the final answers by performing the proper mathematical operations, and even possibly taking an average of the final calculations in each trial, a sense of rationality develops in a student as well as mental orderliness. Students who do rational things such as physics problem solving and data taking and calculating become rational thinkers. Rational thinkers cannot be easily taken advantage of and tend to be more successful in life.

Therefore, we need the mathematical course, not just for the upper 25% of the typical high school student body, but for all students in the school if possible. Many students will benefit from the mathematical course through a true understanding of the language of the universe

which is mathematics, and the true description of universe which is the mathematical interpretation of nature. Also, the student will enhance his career possibilities by being able to physics, chemistry, and engineering type courses as well as enhance his rationality to be self sufficient. To do the mathematical course for all students, we physics teachers must make an extra effort to help each student with problem solving, and to generate a successful course for the many and not the few by using direct instruction emphasizing skills before theory, and using drills and practices in our physics problem solving so that all in the class may learn physics in its true form, mathematically.

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